Probability of Line-of-Sight in Urban Terrain

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TRAC-Monterey

28 July 2004

Key Players

Researchers

- TRAC-Monterey (project lead)
- Naval Postgraduate School
- USMA

Partners

- TerraSim
- AMSAA
- CACI/JWARS

Clients

- MOUT FACT
- AMSO
- Simulation Community
  - AWARS
  - CBT XXI
  - OneSAF

Who's seen this

- Mike Bauman (Director, TRAC)
- Danny Champion (TRAC-WSMR)
- Lou Fatale (ERDC-TEC)
- CBT XXI/OneSAF/AWARS developers

Agenda

- Background/Motivation
- Methodology
- Results
- Follow-on research

CASTFOREM Complexity Increase+

	Balkans Stryker Bde*	Caspian UA**
Scenario Development Time	2.5 mos x 3 personnel	6 mos x 8 personnel
Number of blue soldiers/systems	1,887	3,694
Number of threat soldiers/systems	922	5,221
Number of decision tables	2,224	13,479
Number of combat orders	9,537	62,464
Mission time	33 hrs	44 hrs
Computer run time (1 rep)	4.5 hrs	60 hrs
Output file size	3 Gb	158 Gb
Machine speed	1 GHz	3 GHz
Virtual memory required	128 Mb	3 Gb

*** BBS 21.0, Stryker Bde Scenario, Developed 2000**

**** Caspian 20.0, FCS UA Scenario, Developed 2003**

+ Source: Mackey, Doug. "Overview of Network Models," presented at the CASTFOREM Users Group Meeting, 13 July 2004, White Sands Missile Range, NM.

PLOS: what, why, when?

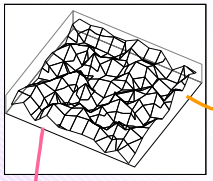
- **What**
  - **Probability of Line of Sight**
  - **Uses digital elevation data to estimate the probability that LOS exists at a given range, elevation, and terrain type.**
  - **Can be defined for any size terrain “box”**
- **Why** ➡ **faster simulation run time**
  - **Fast LOS determination**
- **When**
  - **Use when the need for simulation speed allows for compromises in LOS accuracy.**
  - **Large scale simulations with many targets and many sensors**

Pedigree

- Past 30 years – several attempts to represent terrain (and its effects) probabilistically
  - Parry
  - Others
  - Open terrain
- More recently
  - Blacksten, Burdick – PLOS for JWARS
  - Champion, Fatale – effects of vegetation on LOS

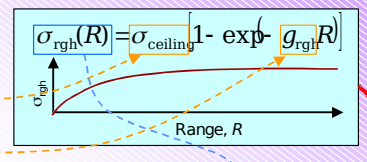
Background – PLOS in Open Terrain (JWARS)

Result: A New PLOS/Roughness Model



Step 1. Precompute effective terrain roughness and fit roughness curve parameters $\sigma_{ceiling}$ and g_{rgh} to give good fit.

$$\sigma_{rgh}(R) = \sigma_{ceiling}\left[1 - \exp\left(-g_{rgh}R\right)\right]$$

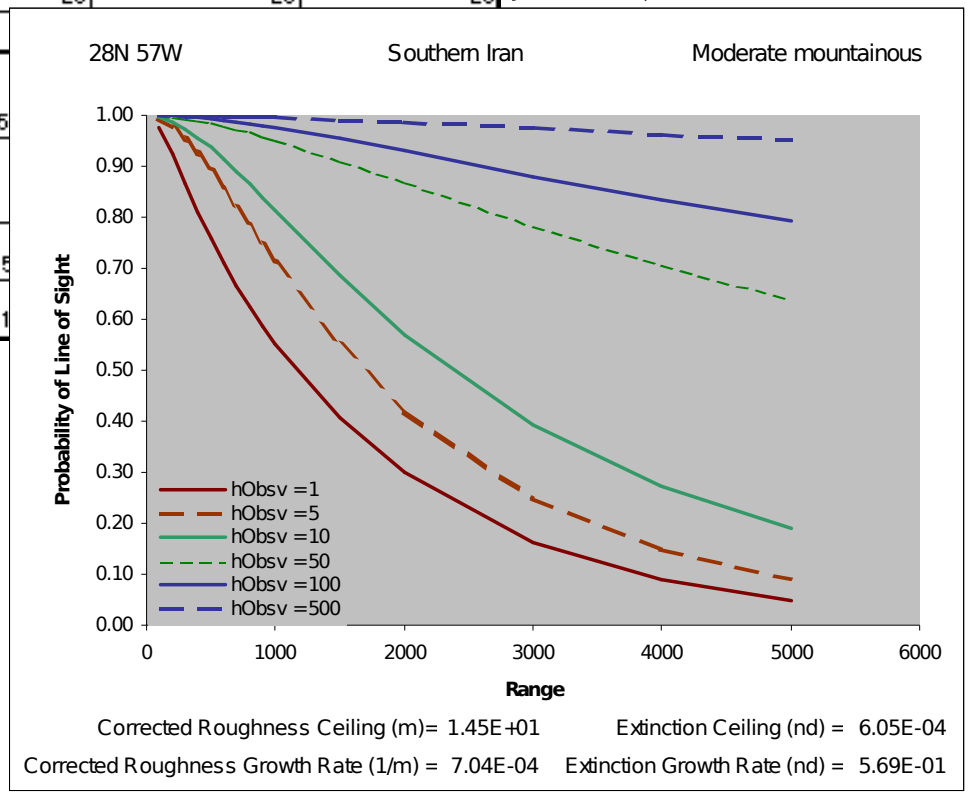


Step 2. Precompute PLOS curves for ter grid and fit extinctio coefficient curve parameters $c_{ceiling}$ a g_{xtnct} to give good fit

Step 3. To obtain PLOS during JWARS executio form composite function curves from Steps 1 an

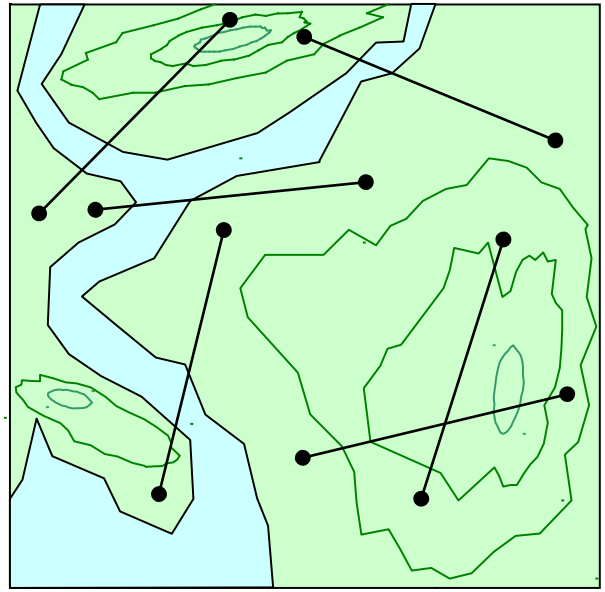
Voila! Shoulc

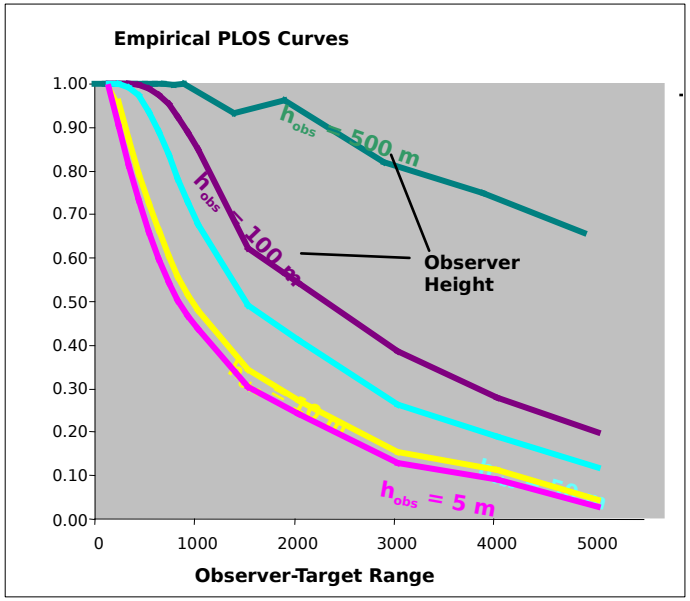
Location	Eastern coastal Saudi Arabia	North eastern coastal Saudi Arabia	Western Iran	Southern Iran
General Description	Flat coastal	Flat coastal	Moderate mountainous	Moderate mountainous
Latitude	25	28	28	28
Longitude	50			
Corrected Roughness Growth Rate (m/m)	2.25E-04	5		
Corrected Roughness Ceiling (m)	4.31E+00			
Extinction Growth Rate (m/m)	1.08E+00	5		
Extinction Ceiling (m^{-1})	2.52E-04	1		



Source: Blacksten, H. Ric, Burdick, Charles D., Grell, Mihly G. [2002], *Probability of Line-of-Sight (PLOS) and Roughness Enhancements for JWARS 1.5*, San Jose: INFORMS/MAS

JWARS Empirical PLOS curves

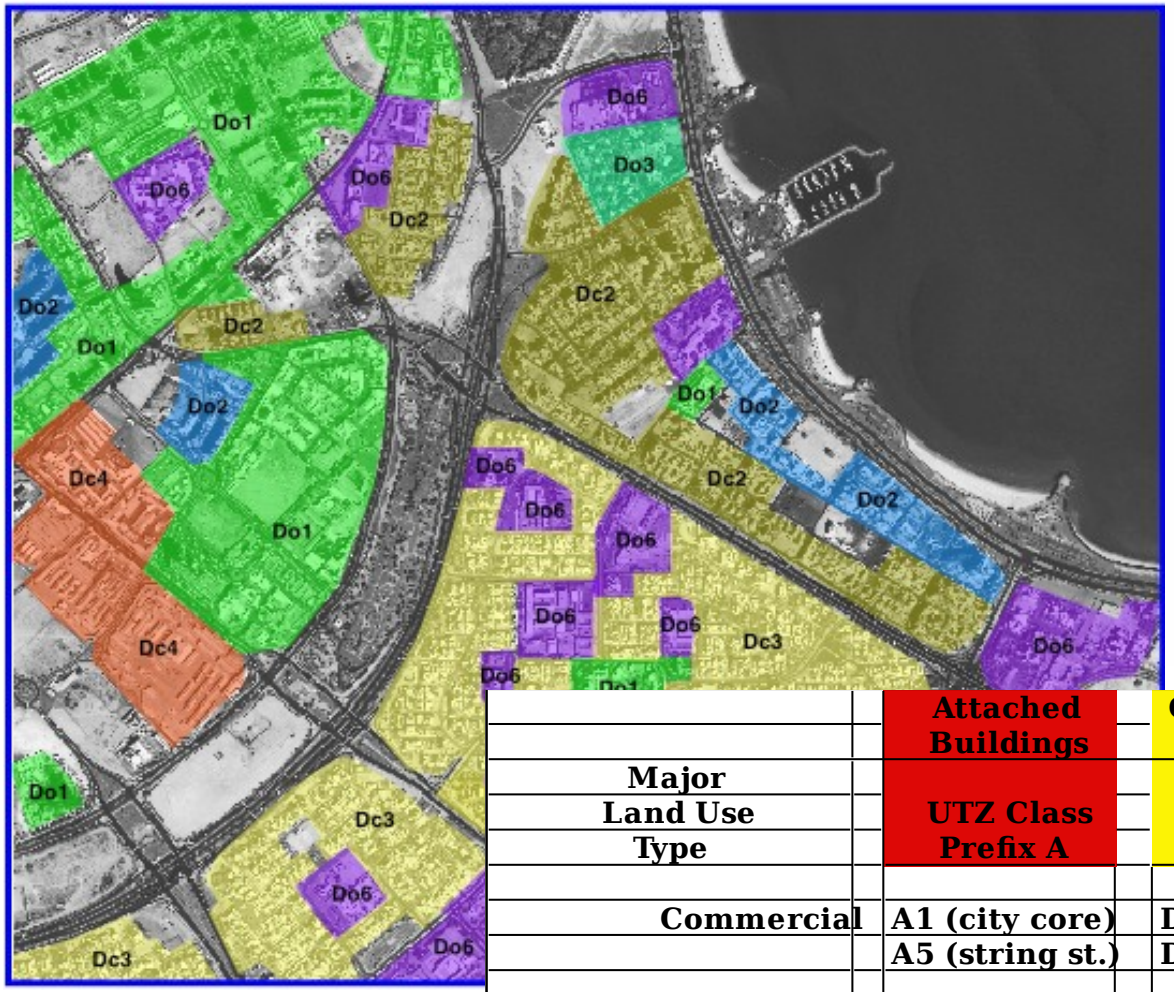




- **Produce empirical PLOS curves by randomly dropping observer-target vectors of prescribed range on terrain grid of interest**
- **Repeat for all observer heights**

Background: Urban Terrain Zones (UTZ)

- **Richard Ellefsen (Professor Emeritus, SJSU) developed Urban terrain zones to classify areas in the urban landscape with an emphasis on the military significance of differences among areas.**
- **Typical parameters (that distinguish a UTZ)**
  - **building dimensions, spacing, construction type, street widths, set back, vegetation, etc.**
- **Examples**
  - **A1: tall buildings; city core; no building spacing.**
  - **Dc3: low, closely-spaced residential buildings.**
  - **Do4: low, widely-spaced industrial/storage buildings located at the edge of cities near major highways.**

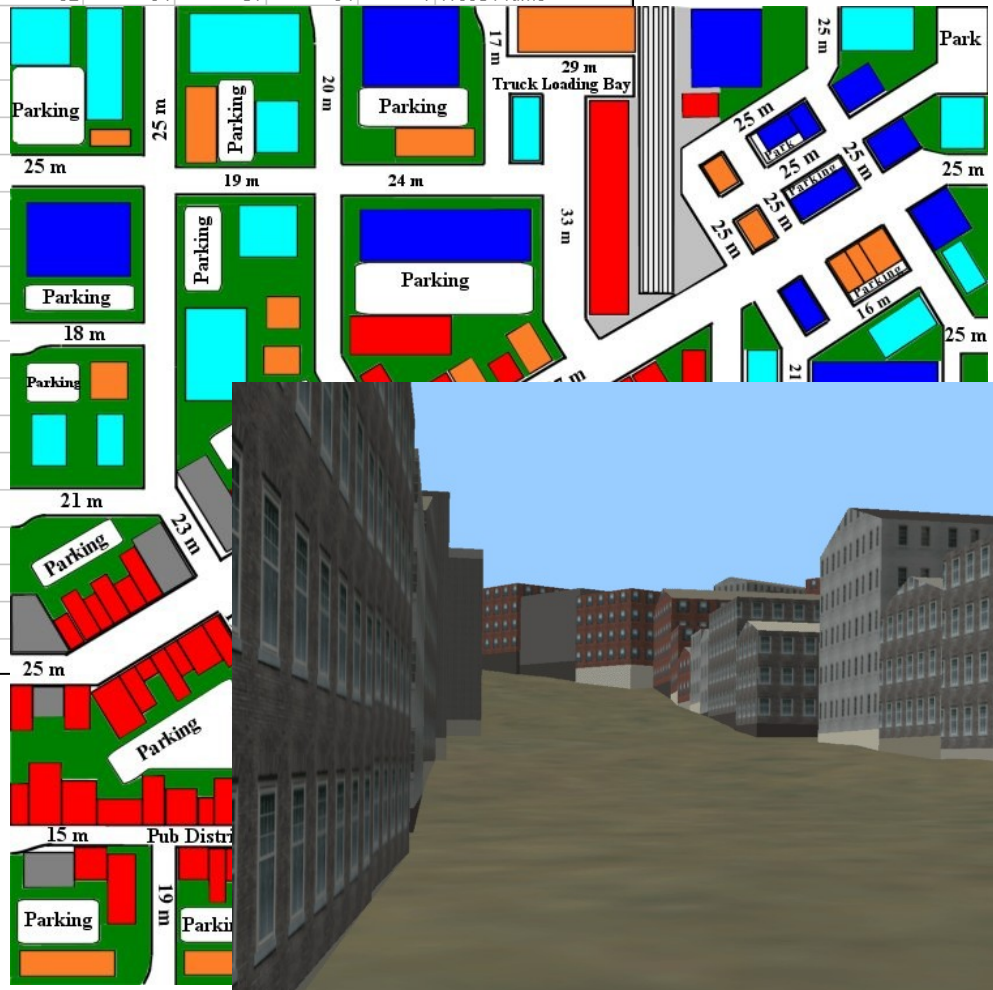


Major Land Use Type	Attached Buildings UTZ Class Prefix A	Closely Spaced Buildings UTZ Class Prefix Dc	Widely Spaced Buildings UTZ Class Prefix Do
Commercial	A1 (city core)	Dc1 (urb redev.)	Do1 (shop. mall)
	A5 (string st.)	Dc5 (string st.)	Do5 (string st.)
Residential	A2 (apts)	Dc2 (apts)	Do2 (apts)
	A3 (houses)	Dc3 (houses)	Do3 (houses)
Industrial/ Storage*	A4 (core edge)	Dc4 (RR/dock)	Do4 (truck)
Institutional	(A6)	(Dc6)	Do6 (admin/cult.)

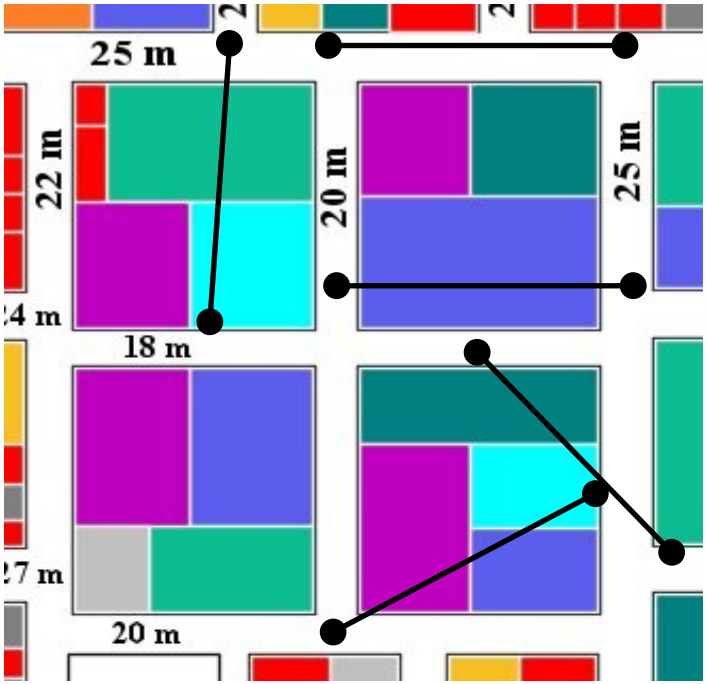
Terrain Data Inputs

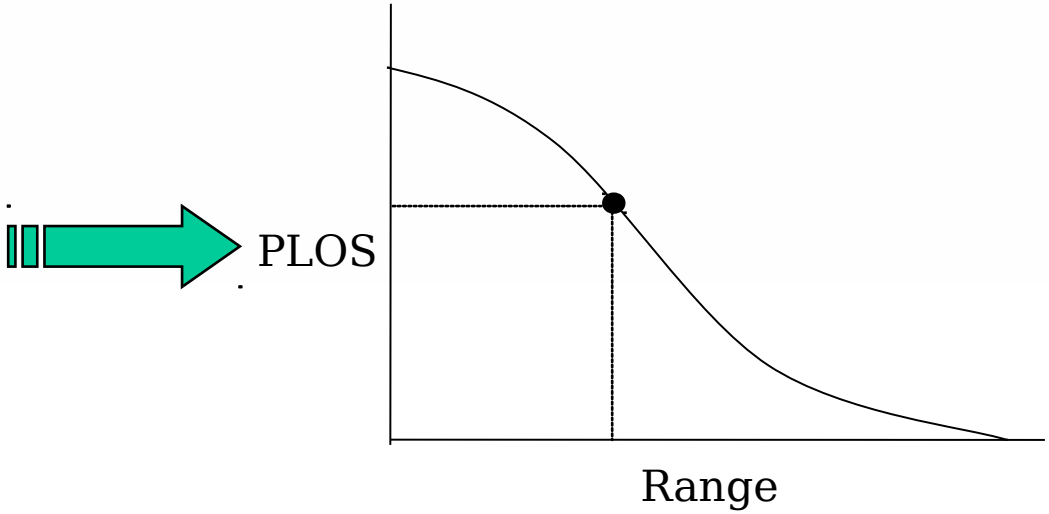
- **“2.5-D” geo-typical urban templates developed by AMSAA**
  - **Data consists of building corners and heights**
  - **Depict typical patterns for each urban terrain type (building dimensions, spacing, roads, other features)**
- **True 3-D urban templates created by laying AMSAA’s urban templates on top of a terrain “skin”**
  - **Data consists of LIDAR-like elevation postings**

	A	B	C	D	E	F	G	H	I	J	K
1	Commercial/Commercial Ribbon/										
2	121										
3	Building #	(x,y lower left corner)		(x,y lower right corner		(x,y upper right corner		(x,y upper left corner)		(Number	stories, material)
4	1	0	45	46	45	46	1	0	1	2	Concrete Block
5	2	58	87	86	87	86	1	58	1	1	Concrete Block
6	3	61	107	92	107	92	94	61	94	1	Wood Frame
7	4	137	51	222	51						
8	5	134	120	158	120						
9	6	188	112	221	112						
10	7	270	61	344	61						
11	8	295	115	356	115						
12	9	385	118	406	118						
13	10	389	35	479	35						
14	11	444	236	474	236						
15	12	522	62	576	62						
16	13	515	85	543	85						
17	14	544	143	558	134						
18	15	581	110	605	96						
19	16	609	102	622	94						
20	17	571	186	586	177						
21	18	607	164	649	138						
22	19	610	249	625	240						
23	20	643	81	671	64						
24	21	670	124	698	107						



PLOS Methodology



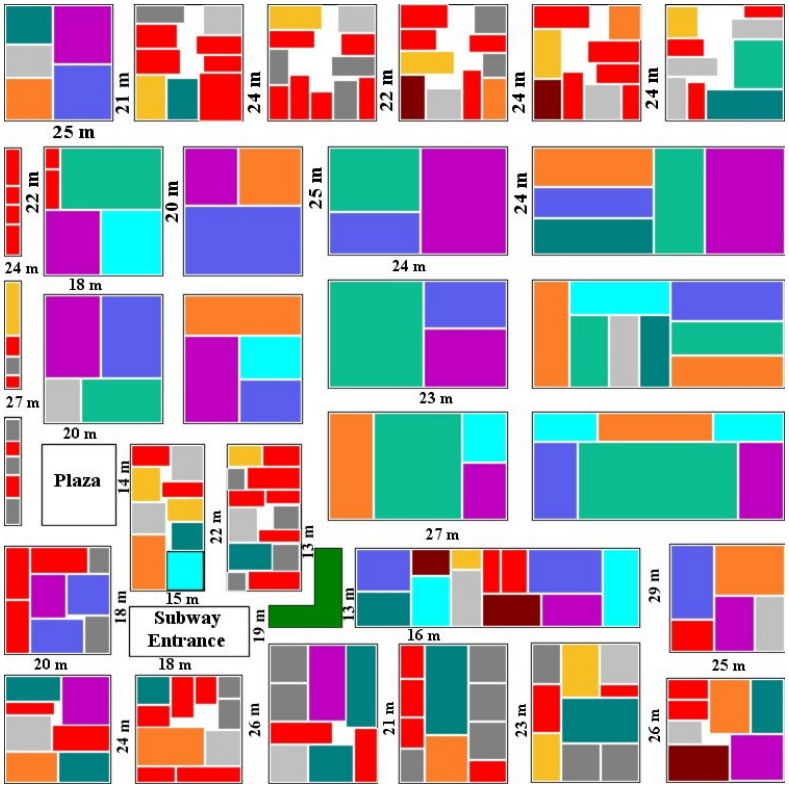


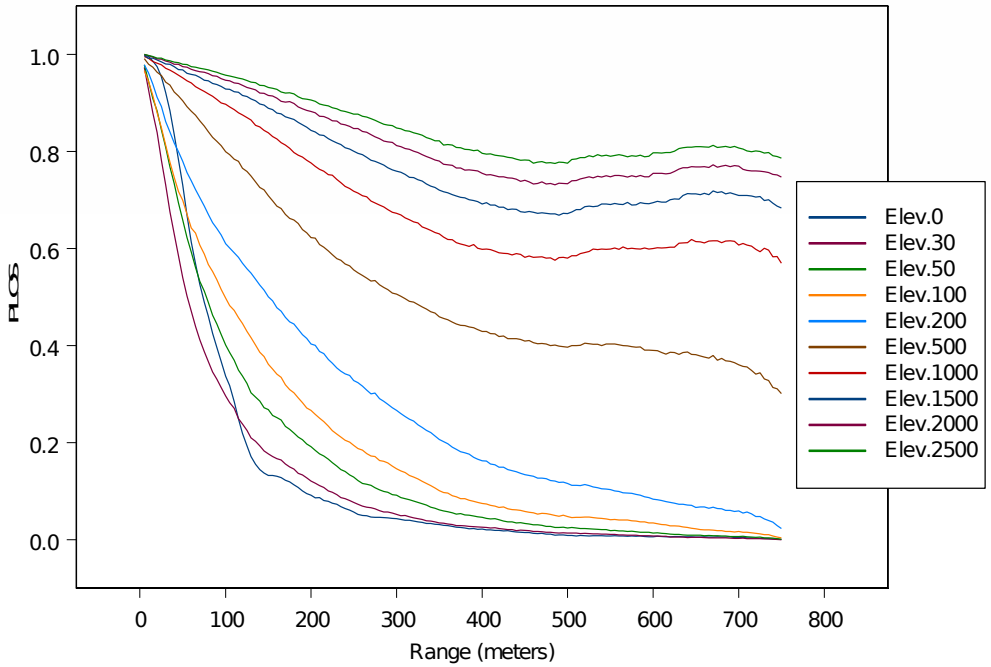
Fix observer & target height, terrain type, and <u>range</u>

To produce one data point on one curve

Results (1 of 3)

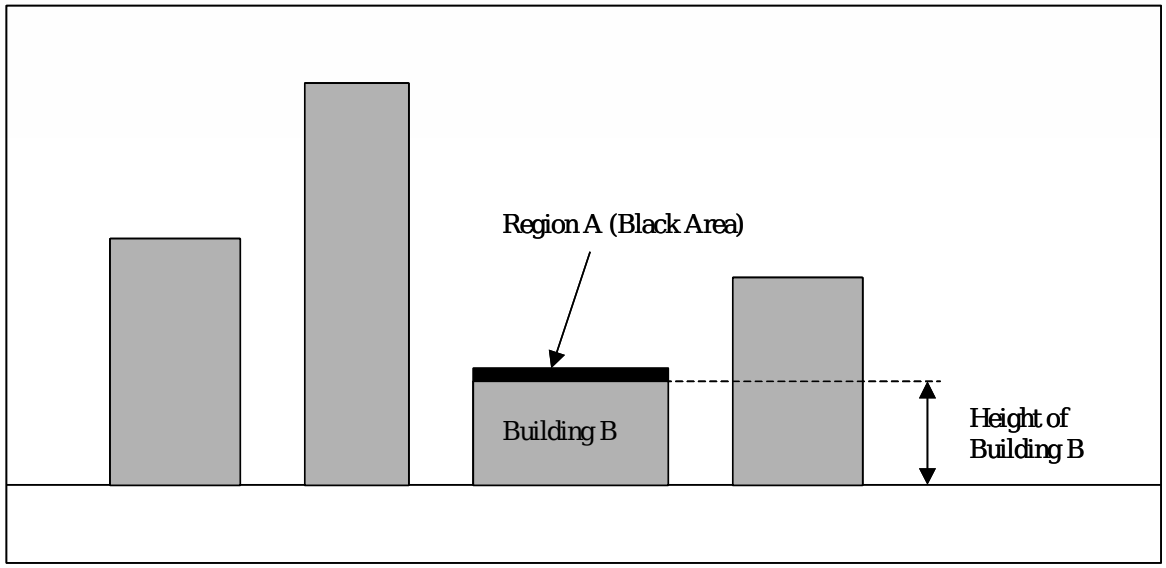
City Core

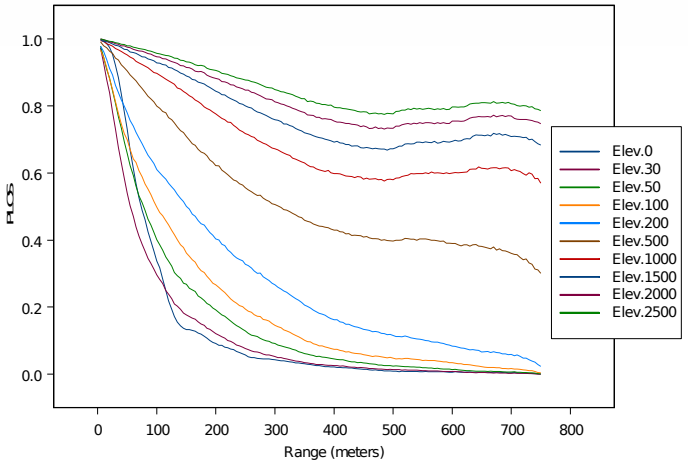




Apparent Anomalies

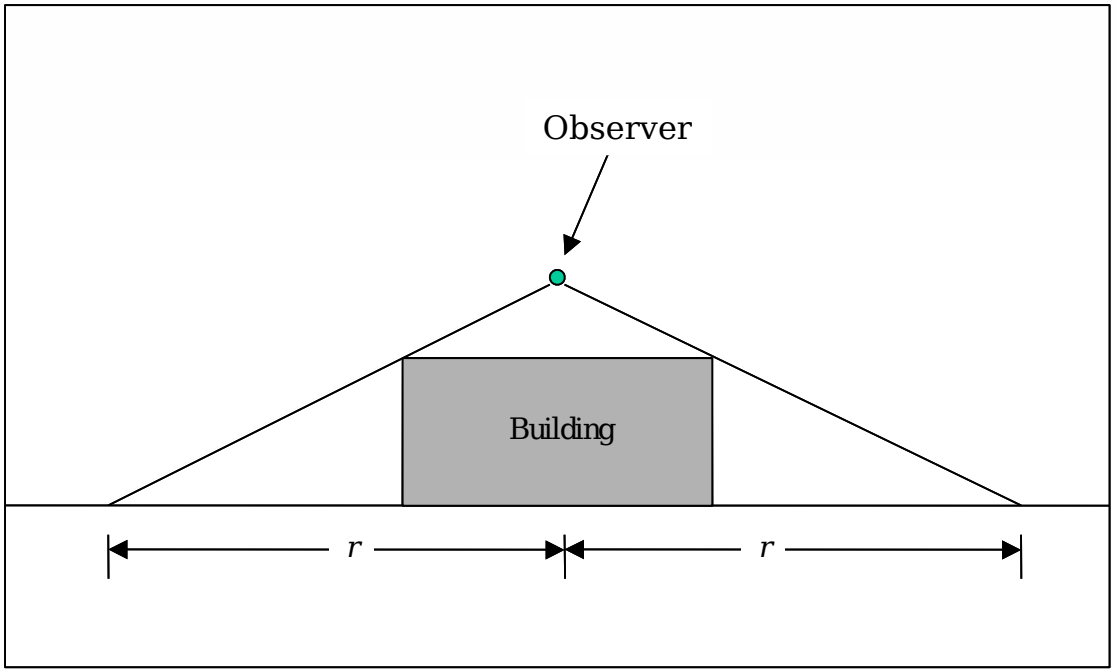
1. PLOS for the zero-elevation observer is higher than that for higher-elevation observers for short ranges.

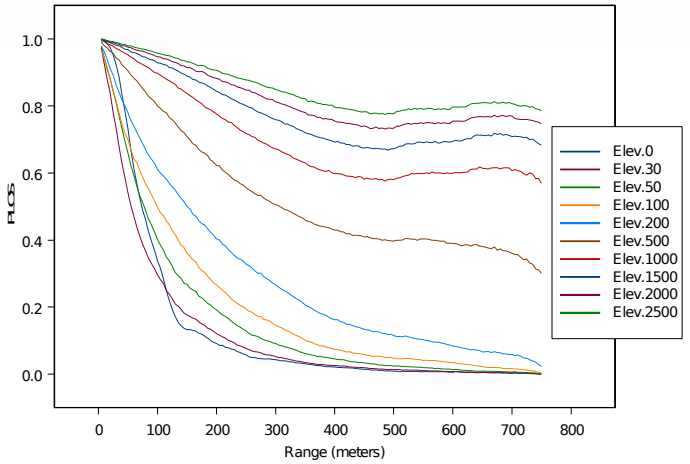




Apparent Anomalies

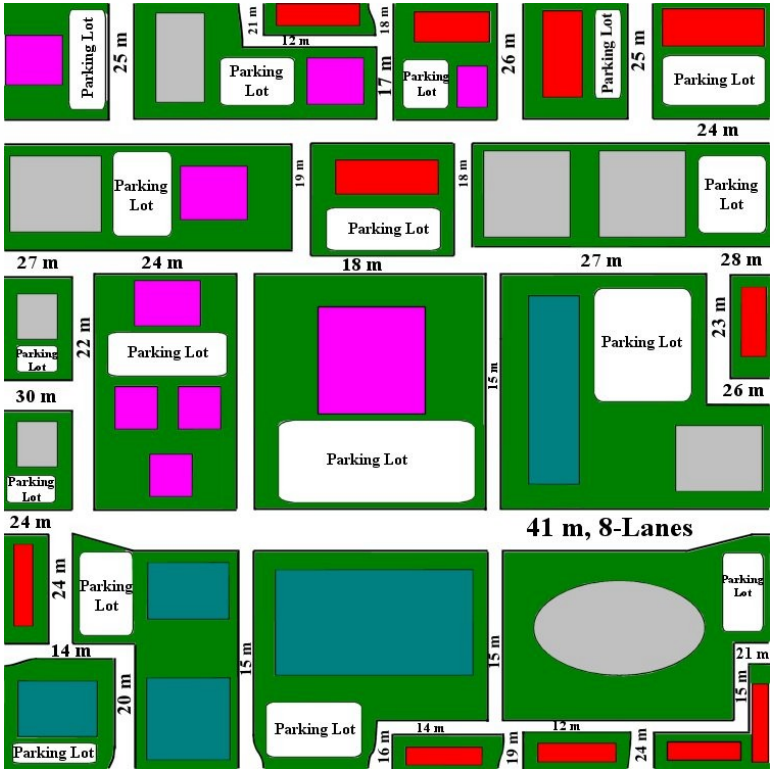
2. At certain ranges, PLOS for high observer elevations increases with range.

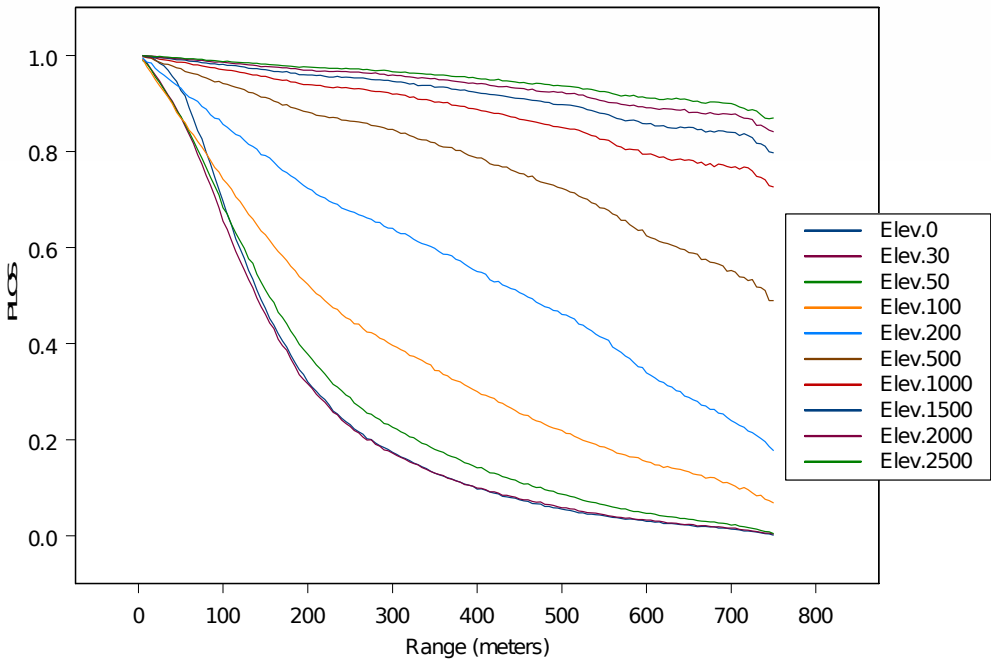




Results (2 of 3)

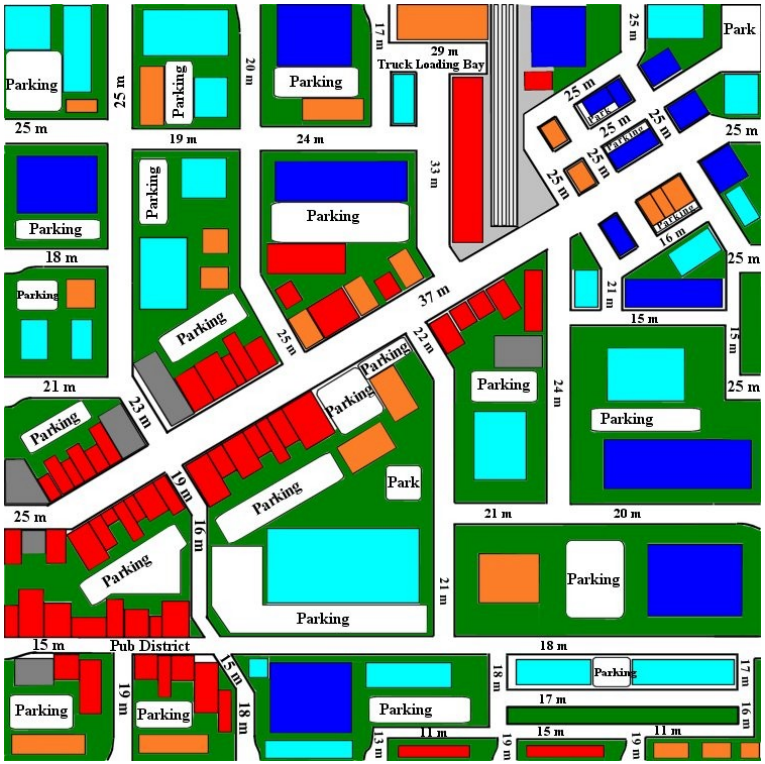
Outlying High Rise Area

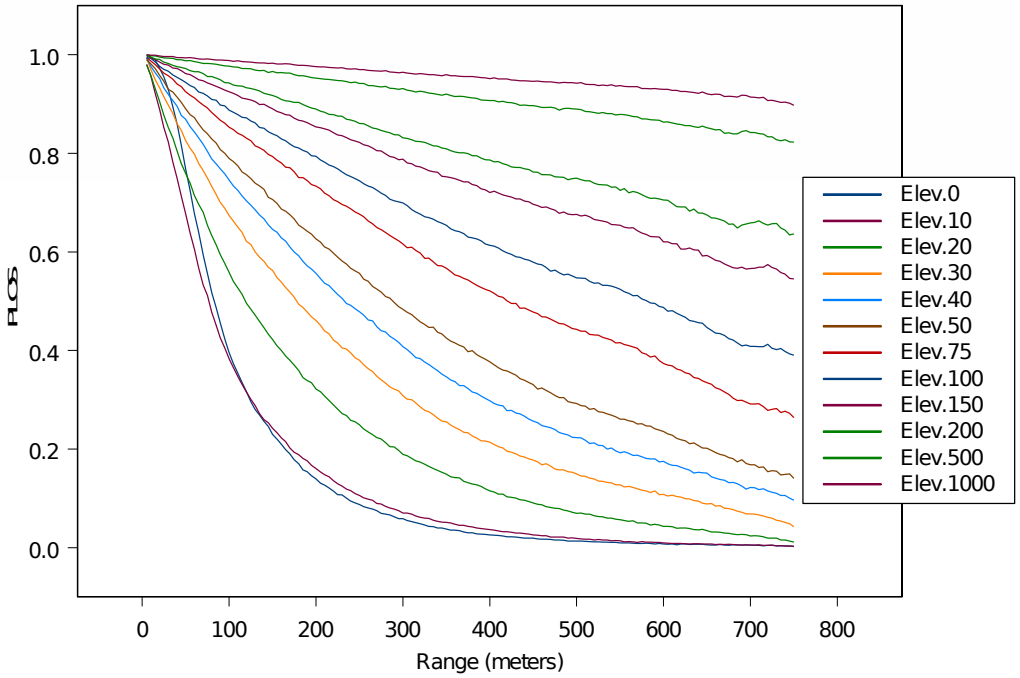




Results (3 of 3)

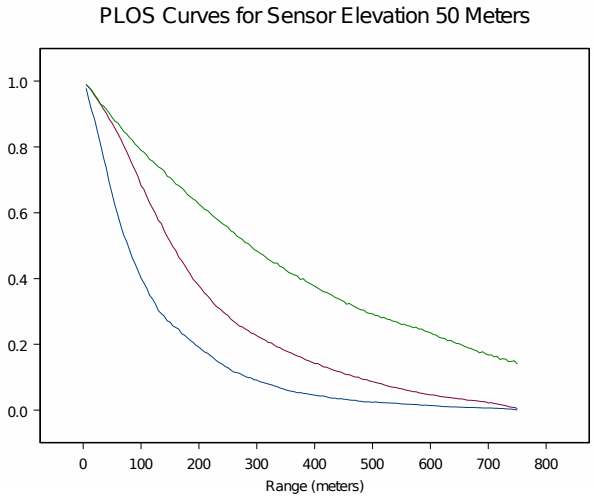
Commercial Ribbon

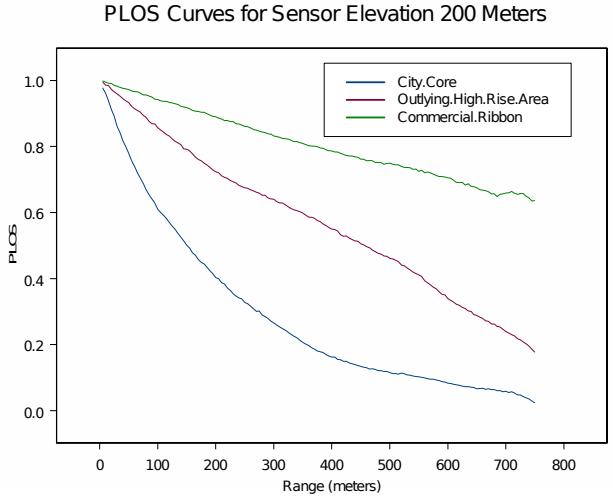




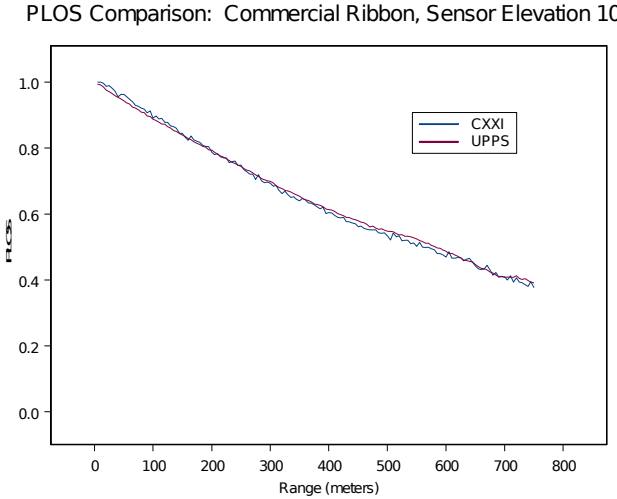
Some Sanity Checks

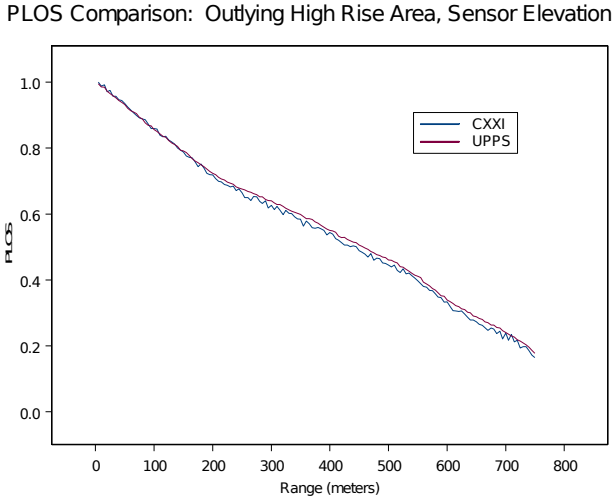
Comparison of results from different terrain types





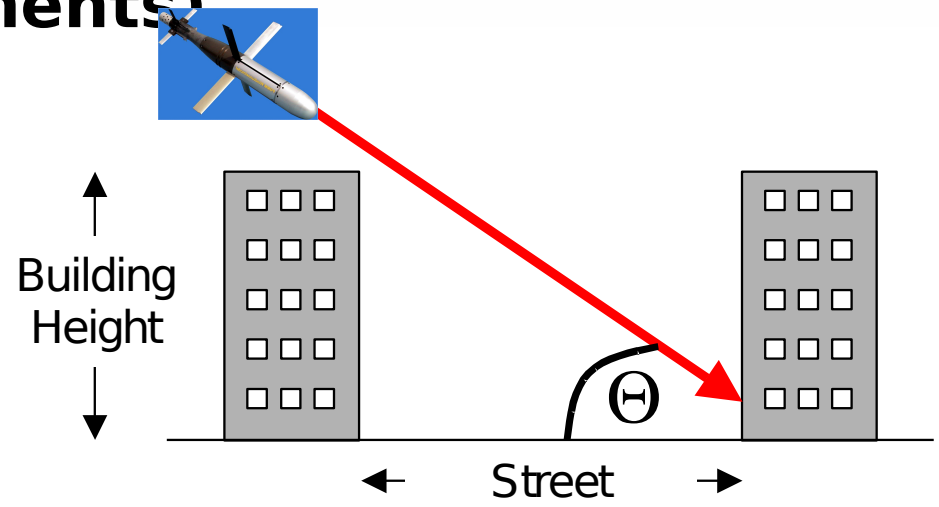
Comparison of results with those obtained using Combat[XXI]





Impact

- **Can produce PLOS curves (or data tables) for any observer height and target height for the three urban terrain types shown**
- **This data can be used now in appropriate simulations or to support studies (e.g., AMSAA study on use of laser guided munitions in urban environments)**



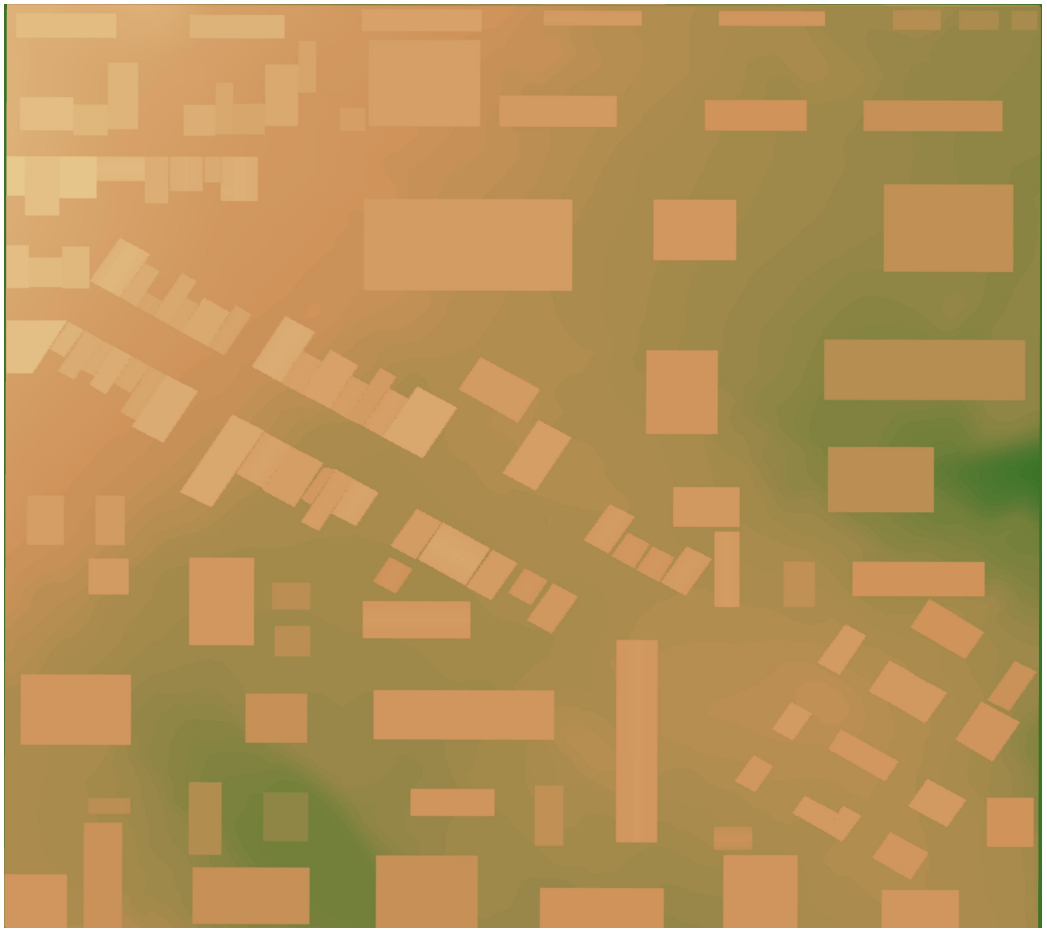
Turnbull, Douglas. "Analysis of the Suitability of Laser-Guided Munitions for Use in Urban Environments (Draft)," USAMSAA, 2004.

Future Work

- **Develop analytical urban PLOS models**
  - **Need to quantify urban terrain type (need an analog to roughness for open terrain)**
  - **Possibilities include one or more statistics that characterize a particular type of urban terrain (average building height; building density; average street width; etc.)**
- **Estimate PLOS as a function of target type**

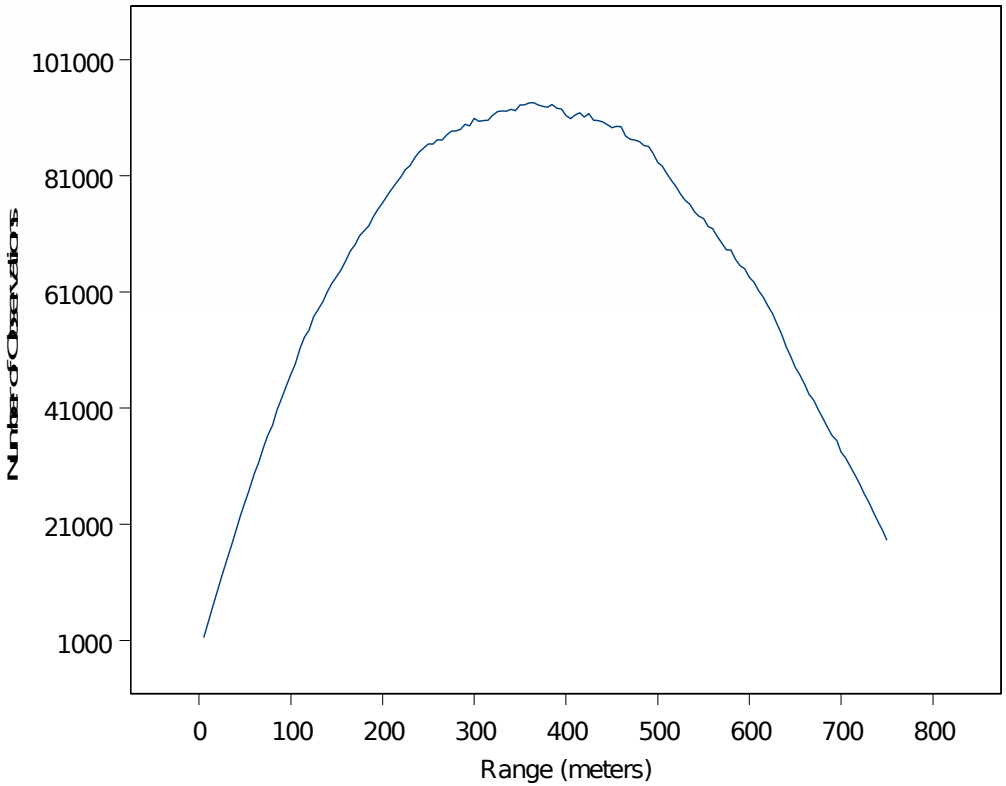
Future Work (cont'd)

- **Further development is required in order to produce PLOS data for "3-D" urban terrain**



Future work (cont'd)

- **Does bin sample size distribution bias the results?**



Assumptions/Limitations/Caveats

- **Our results have not (yet) been validated.**
- **Only buildings (now) and terrain “skin” (future) block LOS – vegetation, lampposts, vehicles, etc. not considered.**
- **PLOS approach is suitable for large scenarios only (definition of “large” is situation dependent).**
- **PLOS would actually vary by target type, but this is not reflected in our results.**
- **Implementation of a PLOS approach in a simulation might warrant the adoption of additional rules; e.g., if blue has LOS to red, then red has LOS to blue.**